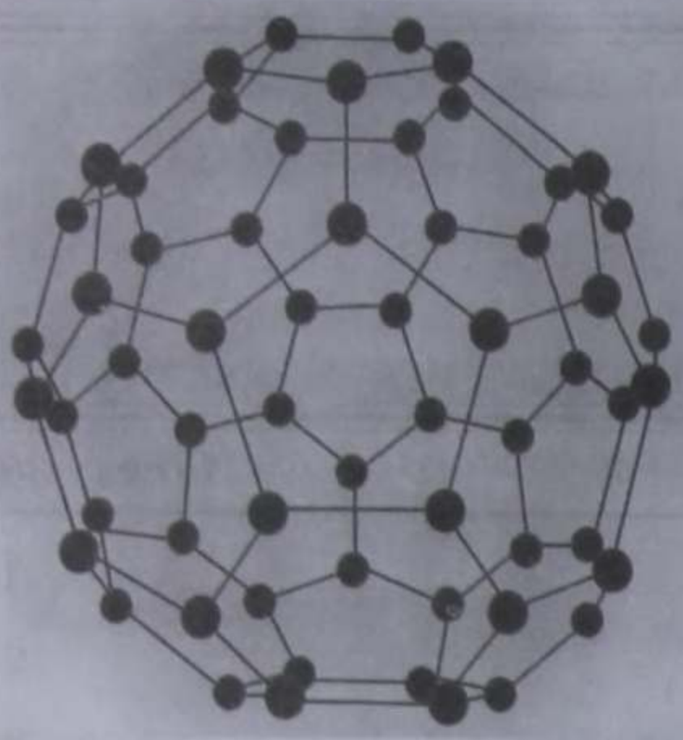


9

STUDY OF THE FIRST ELEMENT – HYDROGEN

SCOPE OF SYLLABUS

Position of the non-metal (Hydrogen) in the periodic table and general group characteristics with reference to valency electrons, burning, ion formation applied to the above mentioned element.

(*i*) ***Hydrogen from water***

(*ii*) ***Hydrogen from dilute acids***

(*iii*) ***Hydrogen from alkalies.***

Hydrogen from water : Cold water and metals; hot water and metals; steam and metals; steam and non-metals. Application of activity series for the above mentioned preparations. Displacement of hydrogen from dilute sulphuric acid or hydrochloric acid by zinc or iron (no reaction with copper). Displacement of hydrogen from alkalies (NaOH, KOH) by Zn, Al – unique nature of these elements.

(*iv*) ***The preparation and collection of hydrogen by a standard laboratory method other than electrolysis.***

In the laboratory preparation, the reason for using zinc, the impurities in the gas, their removal and the precautions in the collection of the gas must be mentioned.

Industrial manufacture of hydrogen by Bosch process with main reactions and conditions; separation of CO_2 and CO from it.

IMPORTANT POINTS TO REMEMBER

1. The **first element** that existed in the universe was **hydrogen**.
2. **Hydrogen** in the **sun** undergoes the process of **nuclear fusion** to form **helium** with the liberation of **energy** in the form of **heat** and **light**.
3. The **credit** of **discovery** of **hydrogen** goes to **Henry Cavendish.**
4. **Antoine Lavoisier** named the gas as **hydrogen**, *i.e.*, **water producer**.
5. **Hydrogen** is the **first element** present in the **periodic table**.
6. **Position** of **hydrogen** is **controversial** as it is placed in **group 1** (alkali metals) and **group 17** (halogens).
7. **Hydrogen resembles** the **alkali metals** in the following ways :

   (*i*) **Electronic configuration :** Like alkali metals, hydrogen has also got one electron in its valence shell.

   (*ii*) **Formation of cations :** Like alkali metals, hydrogen loses electron and forms cation.

   $H - e^- \longrightarrow H^+$ (Hydrogen)

   $Na - e^- \longrightarrow Na^+$ (Alkali metal)

   (*iii*) **Formation of compounds :** Hydrogen readily forms stable compounds with oxygen, sulphur and chlorine.

H_2O = Water

H_2S = Hydrogen sulphide

HCl = Hydrogen chloride

In the similar way the alkali metals form oxides, sulphides and chlorides

Na_2O = Sodium oxide

Na_2S = Sodium sulphide

NaCl = Sodium chloride

(*iv*) **Hydrogen** burns in **oxygen** to form **water** (neutral oxide).

$$2H_2 + O_2 \rightarrow 2H_2O.$$

8. **Hydrogen resembles halogens** in the following ways :

(*i*) **Electronic configuration :** Both hydrogen and halogen require one electron to complete their duplet and octet respectively, hence they gain electrons to acquire stable configuration. Therefore, they are electronegative and monovalent.

$$\underset{1}{H} + e^- \longrightarrow \underset{2}{H^-}$$

$$\underset{2,8,7}{Cl} + e^- \longrightarrow \underset{2,8,8}{Cl^-}$$

(*ii*) **Atomicity :** It is the number of atoms present in one molecule of an element. Both hydrogen and halogens are diatomic, *i.e.*, having two atoms in its one molecule.

Hydrogen — H_2

Fluorine — F_2

Chlorine — Cl_2

Bromine — Br_2

Iodine — I_2

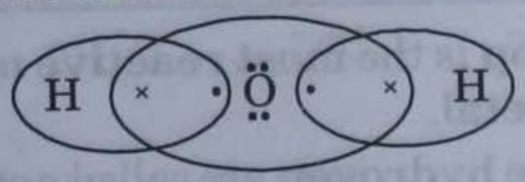
9. **Hydrogen** has **three isotopes**, *i.e.*, these are the **atoms** of **same element** having **same atomic number** but **different mass number**.

Isotopes differ in **number** of **neutrons**.

Name of the Isotope	*Symbol*	*Mass Number*	*Atomic Number*	*Protons*	*Neutrons*	*Electrons*
Protium	^1_1H	1	1	1	0	1
Deuterium	^2_1D or ^2_1H	2	1	1	1	1
Tritium	^3_1T or ^3_1H	3	1	1	2	1

10. **Protium** has **no neutron**.

11. **Hydrogen** in **combined state** occurs in the form of **water (H_2O)**.



H—Ö—H

Formation of polar covalent bond in water

Water forms **polar covalent bond**.

12. All plants and animals have **hydrogen** in the form of **carbohydrates, fats** and **proteins**.

13. **Organic compounds** essentially contain **hydrogen** in **combination** with **carbon**.

14. **General methods of preparation of Hydrogen.**

(*i*) **By action of metals with cold water : Sodium, potassium** and **calcium** react with **cold water** to form its respective **metallic hydroxides** (soluble) with the **liberation** of **hydrogen**. It is not a safe method to prepare hydrogen gas in laboratory as the reaction sometimes proceeds with an explosion.

Metal + Cold water ⟶ Metallic hydroxide + Hydrogen

$$2Na + 2H_2O \longrightarrow 2NaOH + H_2$$

Sodium + Water ⟶ Sodium hydroxide + Hydrogen

$$\underset{\text{Potassium}}{2K} + \underset{\text{Water}}{2H_2O} \longrightarrow \underset{\substack{\text{Potassium}\\ \text{hydroxide}}}{2KOH} + \underset{\text{Hydrogen}}{H_2}$$

$$\underset{\text{Calcium}}{Ca} + \underset{\text{Water}}{2H_2O} \longrightarrow \underset{\text{Calcium hydroxide}}{Ca(OH)_2} + \underset{\text{Hydrogen}}{H_2}$$

Both **sodium** and **potassium** react **vigorously** with **cold water.** The **solution** thus **produced as a result** of **reaction turns red litmus blue** showing that the **solution formed** is **basic** or **alkaline** in nature.

(*ii*) **By the reaction of metals with steam :**

Heated metal + Steam $\longrightarrow$ Metallic oxide + Hydrogen

$$Mg + \underset{\text{Steam}}{H_2O} \longrightarrow MgO + H_2$$

$$Zn + \underset{\text{Steam}}{H_2O} \longrightarrow ZnO + H_2$$

$$\underset{\text{Heated}}{3Fe} + 4H_2O \rightleftharpoons Fe_3O_4 + 4H_2$$

(*iii*) **By the reaction of dilute acids with active metals :**

(*a*) **Activity series :** The series in which the metals are arranged in the decreasing order of their reactivity is called activity series.

K	Potassium	Reactivity Increases →	← Reactivity Decreases
Ca	Calcium		
Na	Sodium		
Mg	Magnesium		
Al	Aluminium		
Zn	Zinc		
Fe	Iron		
Pb	Lead		
[H]	Hydrogen		
Cu	Copper		
Hg	Mercury		
Ag	Silver		
Au	Gold		
Pt	Platinum		

(*b*) The **metal** lying at the **top** is the **most reactive metal** and the **metal** present at the **bottom** is the **least reactive metal.**

(*c*) The **metals** placed **above hydrogen** are called **active metals** as they can displace **hydrogen** readily from **water** and **dilute acids.**

(*d*) Highly reactive metals like **sodium, potassium** and **calcium** react **vigorously** at ordinary temperature with **dilute acids** liberating **hydrogen.**

$$2Na + \underset{\text{dil.}}{2HCl} \longrightarrow 2NaCl + H_2$$

$$2K + \underset{\text{dil.}}{2HCl} \longrightarrow 2KCl + H_2$$

$$Ca + \underset{\text{dil.}}{2HCl} \longrightarrow CaCl_2 + H_2$$

(*e*) Metals like **magnesium, zinc, aluminium, iron,** etc. react **moderately** at ordinary temperature with **dilute acids** to liberate **hydrogen.**

Metal	+	Dil. acid	⟶	Salt	+	Hydrogen
Mg	+	2HCl (dil.)	⟶	$MgCl_2$	+	H_2
Mg	+	H_2SO_4 (dil.)	⟶	$MgSO_4$	+	H_2
Zn	+	2HCl (dil.)	⟶	$ZnCl_2$	+	H_2
Zn	+	H_2SO_4 (dil.)	⟶	$ZnSO_4$	+	H_2
2Al	+	6HCl (dil.)	⟶	$2AlCl_3$	+	$3H_2$
2Al	+	$3H_2SO_4$ (dil.)	⟶	$Al_2(SO_4)_3$	+	$3H_2$
Fe	+	2HCl (dil.)	⟶	$FeCl_2$	+	H_2
Fe	+	H_2SO_4 (dil.)	⟶	$FeSO_4$	+	H_2

(*f*) **Nitric acid** reacts with only **magnesium** and **manganese** to liberate **hydrogen**. With **rest** of the **metals** it produces **oxides** of **nitrogen** or **ammonium nitrate** and **not hydrogen** as it is an **oxidising agent**.

Mg	+	$2HNO_3$ (V. dil.)	⟶	$Mg(NO_3)_2$	+	H_2
Mn	+	$2HNO_3$ (V. dil.)	⟶	$Mn(NO_3)_2$	+	H_2

(*g*) **Lead** is **not used** for the **preparation** of **hydrogen** by using **dilute hydrochloric acid** and **dilute sulphuric acid** because the **products** are **insoluble lead chloride** and **lead sulphate** which **settle** on **fresh lead metal** and thus, **prevents** the **reaction** of **metal** with **acid**.

(*iv*) **By the action of alkalies with metals : Metals** like **zinc**, **aluminium** and **lead** in powder form **dissolve** when boiled with **concentrated sodium hydroxide** or **concentrated potassium hydroxide** to form their **respective soluble complex salts** with the **liberation** of **hydrogen**.

Zn	+	2NaOH (conc.)	$\xrightarrow{\text{boiled}}$	Na_2ZnO_2 (Sodium zincate)	+	H_2
Zn	+	2KOH (conc.)	$\xrightarrow{\text{boiled}}$	K_2ZnO_2 (Potassium zincate)	+	H_2
2Al	+	$2NaOH + 2H_2O$ (conc.)	$\xrightarrow{\text{boiled}}$	$2NaAlO_2$ (Sodium aluminate)	+	$3H_2$
2Al	+	$2KOH + 2H_2O$ (conc.)	$\xrightarrow{\text{boiled}}$	$2KAlO_2$ (Potassium aluminate)	+	$3H_2$

15. Laboratory Preparation of Hydrogen.

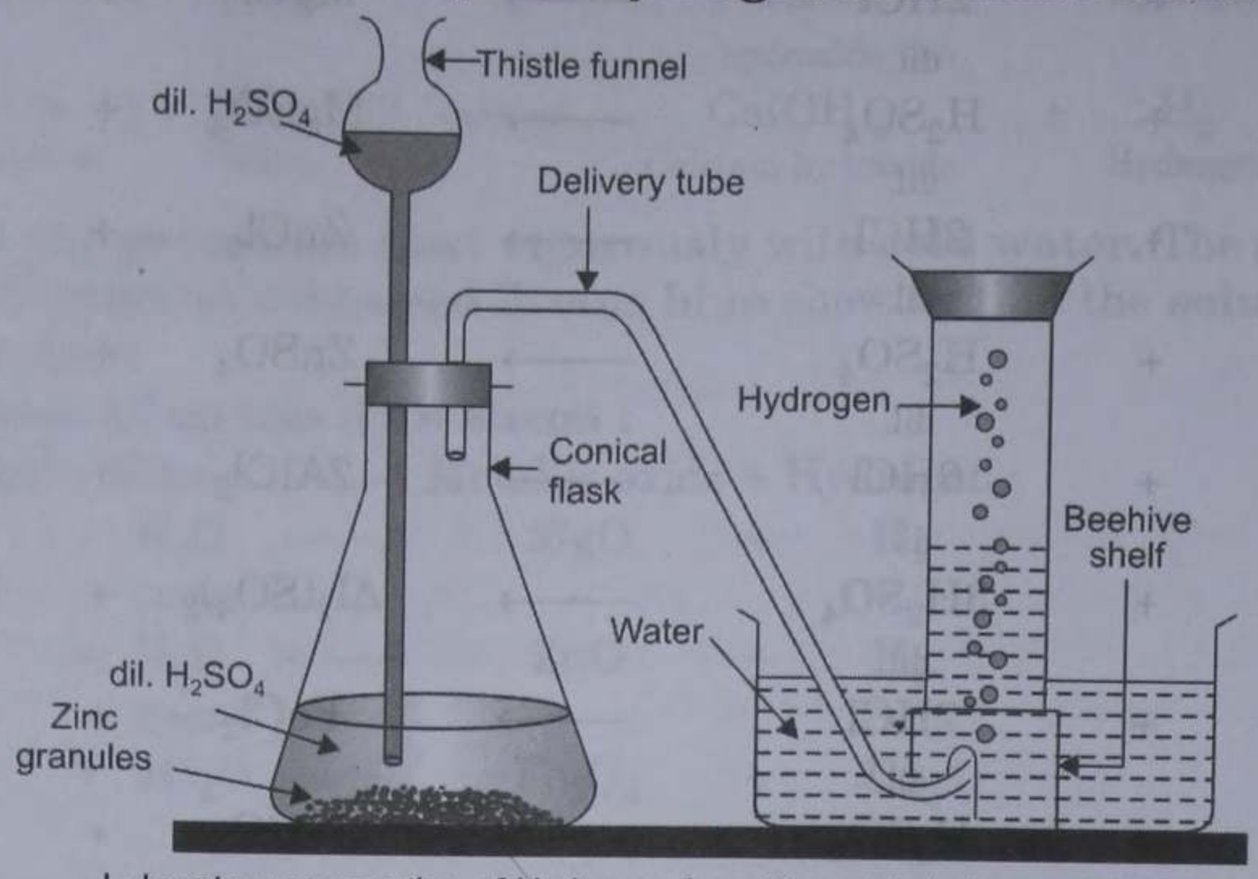
In laboratory, **hydrogen** is **prepared** by the **reaction** of **dilute sulphuric acid** with **granulated zinc**.

Zn	+	H_2SO_4 (dil.)	⟶	$ZnSO_4$	+	H_2

(*i*) **Zinc** is **preferred** to **other metals** because **sodium** and **potassium react explosively** or **violently** with **cold water** or **dilute acids**. In **calcium** and **magnesium**, the **liberation** of **hydrogen** is **very rapid** that it **cannot** be **collected**.

Aluminium gets **coated** with the **thin** but **tough layer** of **oxide** which **prevents** the **reaction** of **metal** with **water** and **dilute acids**.

In **iron**, the **liberation** of **hydrogen** is **very slow** and as **copper** lies **below hydrogen** in **activity series** so, it **cannot displace hydrogen** from **dilute acids**.



Laboratory preparation of Hydrogen from Granulated zinc and dil. H_2SO_4

(*ii*) The **apparatus** used for the **preparation** of **hydrogen gas** should be **airtight**. The **lower end** of the **thistle funnel** should **dip** in the **acid** as otherwise the **gas** will **escape** from the thistle funnel. The **apparatus** should be **kept away** from the **flame**.

(*iii*) **Hydrogen** obtained by the reaction of **granulated zinc** with **dilute sulphuric acid** is **not pure**, it contains the **impurities** of the following **gases** :

(*a*)	Sulphur dioxide	— SO_2	(*e*)	Arsine	— AsH_3
(*b*)	Carbon dioxide	— CO_2	(*f*)	Phosphine	— PH_3
(*c*)	Water vapour	— H_2O	(*g*)	Nitrogen dioxide	— NO_2
(*d*)	Hydrogen sulphide	— H_2S			

Although **pure hydrogen** is **odourless** but **because** of the **presence** of the above named **gases** as **impurities** it possesses a **characteristic peculiar odour**.

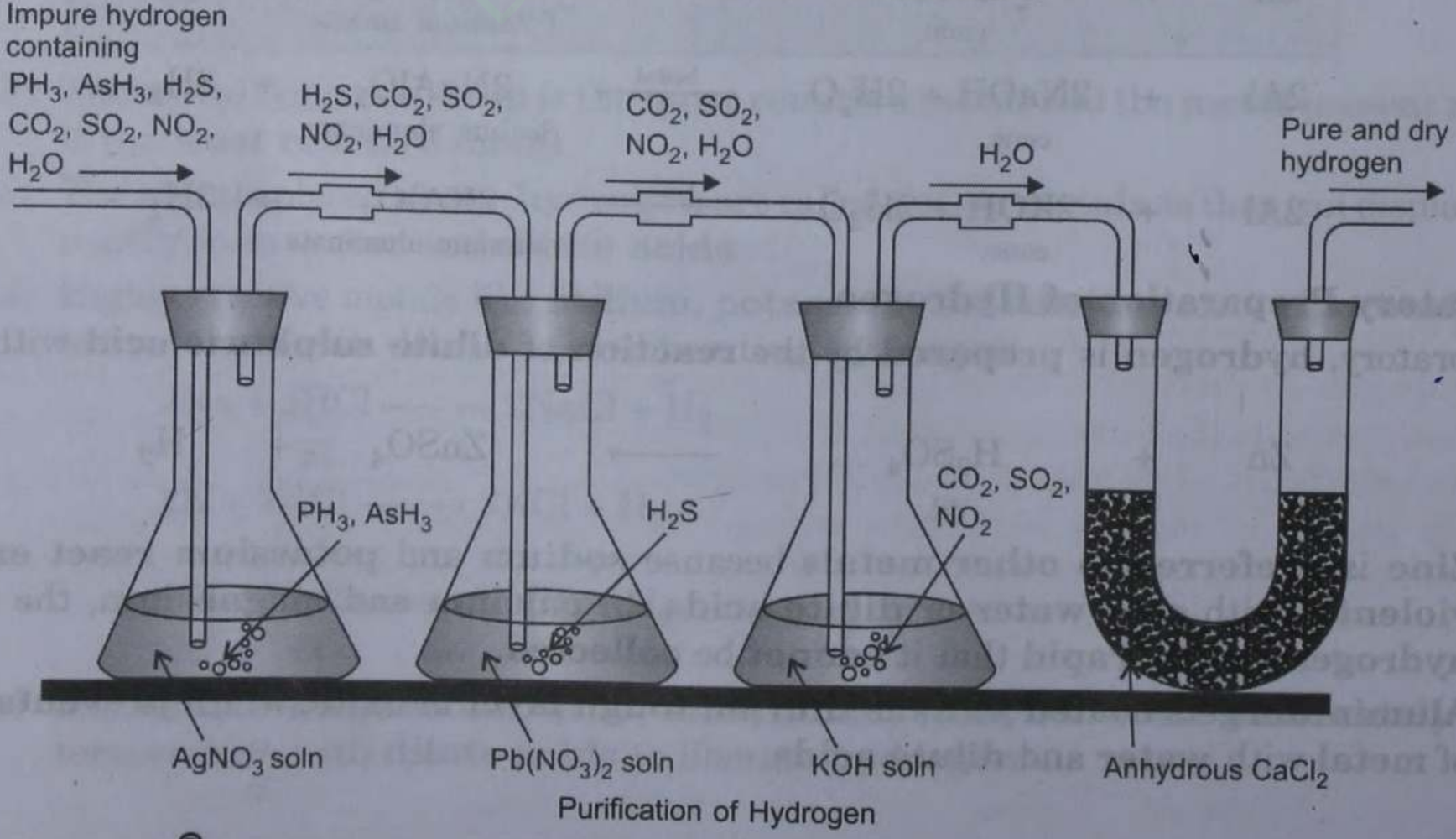
(*iv*) For the **purification** of **hydrogen**, the **impure gas** is passed **through**

(*a*) **Silver nitrate solution :** To absorb **arsine** and **phosphine**.

(*b*) **Lead nitrate solution :** To absorb **hydrogen sulphide**.

(*c*) **Potassium hydroxide solution :** To absorb **carbon dioxide, sulphur dioxide** and **nitrogen dioxide**.

(*d*) **Anhydrous calcium chloride :** To absorb **moisture**.



Purification of Hydrogen

16. **Hydrogen** prepared is **collected** by the **downward displacement** of **water,** after first allowing the **air** to **escape,** as **air** forms an **explosive mixture** with **hydrogen.**

17. **Hydrogen** collected is **dried** by **passing** through **anhydrous calcium chloride**.

18. **Industrially, hydrogen is manufactured by the following methods :**

(*a*) By the electrolysis of acidulated water with platinum electrodes :

When electricity is passed through acidulated water then hydrogen gas is obtained at cathode and oxygen gas is obtained at anode.

$$H_2O \longrightarrow H^+ + OH^-$$

$$HCl \longrightarrow H^+ + Cl^-$$

At cathode : $H^+ + e^- \longrightarrow [H]$

$$2[H] \longrightarrow H_2$$

At anode : $OH^- - e^- \longrightarrow OH$

$$4OH \longrightarrow 2H_2O + O_2$$

(*b*) By Bosch Process : This process involves the following two steps :

(*i*) Preparation of water gas :

When superheated steam at a temperature of 170°C is passed over white hot charcoal it forms **equivolume mixture** of **carbon monoxide** and **hydrogen** called **water gas**. The **reaction** for the **formation** of **water gas** is **endothermic** in nature.

$$\underset{\text{White hot charcoal}}{C} + \underset{\text{Super heated steam}}{H_2O} \xrightarrow{170°C} \underbrace{CO + H_2}_{\text{Water gas}}$$

(*ii*) Removal of impurities (carbon monoxide) from water gas :

Water gas formed is **mixed** with **twice** the **volume** of **steam** and **passed** over the **catalyst,** which is a **mixture** of **ferric oxide** and **chromium oxide (promoter)** at a **temperature** of **450°C, carbon monoxide** gets **oxidized** to **carbon dioxide**.

$$\underbrace{CO + H_2}_{\text{Water gas}} + H_2O \xrightarrow[450°C]{Fe_2O_3/Cr_2O_3} 2H_2 + CO_2$$

The above **reaction** is called the **water gas shift reaction**.

The **hydrogen obtained** by this process contains the **impurities** of **carbon monoxide** in traces and **carbon dioxide**. **Carbon monoxide** can be **removed** by passing it through **ammoniacal cuprous chloride solution**. **Carbon dioxide** can be **removed** by passing through **cold water under pressure**.

19. **Physical properties of Hydrogen :**

(*i*) **Pure hydrogen** is a **colourless, odourless** and **tasteless** gas. However, **impure hydrogen** has **fishy smell**.

(*ii*) Hydrogen is the **lightest gas**.

(*iii*) Hydrogen is practically **insoluble** in **water**.

20. **Chemical properties of Hydrogen :**

(*i*) Combustibility. Hydrogen is a **combustible** gas but it is **not** a **supporter** of **combustion**. It burns with **pale blue flame**. If hydrogen is **mixed** with **air** or **oxygen** and then **ignited**, it causes **explosion**.

(*ii*) Action towards litmus. Hydrogen is **neutral** towards **litmus**, *i.e.*, it **neither turns red litmus to blue nor blue litmus** to **red**, *i.e.*, it is **neither acidic nor basic** in nature.

(iii) Action with non-metals :

(a) Reaction with Oxygen. It **burns silently** in the **atmosphere** of **oxygen** with **pale blue flame** to form **water**, *i.e.*, the product of **oxidation** of **hydrogen** is **water**.

$$2H_2 + O_2 \longrightarrow 2H_2O$$

(b) Reaction with Nitrogen. The process of manufacturing or synthesis of ammonia from its elements called **Haber's process**.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 + \text{heat}$$

Catalyst	—	Finely divided Iron
Promoter	—	Molybdenum
Temperature	—	450–500°C
Pressure	—	200–1000 atm.

(c) Reaction with Chlorine. Chlorine has **maximum affinity** for **hydrogen**. It readily reacts with **hydrogen** in **diffused sunlight** to form **hydrogen chloride gas**. This reaction **does not** take place in **dark**, however, in **direct sunlight** the reaction proceeds **spontaneously** with an **explosion** to form **hydrogen chloride gas**.

$$H_2 + Cl_2 \xrightarrow[\text{sunlight}]{\text{diffused}} 2HCl$$

(d) Reaction with Sulphur. Hydrogen gas is passed through **boiling sulphur** to form a gas having **rotten egg smell**.

$$H_2 + \underset{\text{boiling}}{S} \longrightarrow \underset{\text{Hydrogen sulphide}}{H_2S}$$

(iv) Reaction with Metals. Metals like **sodium, potassium** and **calcium** on **heating** with **dry hydrogen** form their respective **hydrides**. The hydrides formed are **unstable** and react with **cold water** to form their respective **soluble hydroxide** and **hydrogen gas**.

$$2Na + H_2 \xrightarrow{\Delta} \underset{\text{(Sodium hydride)}}{2NaH}$$

$$2K + H_2 \xrightarrow{\Delta} \underset{\text{(Potassium hydride)}}{2KH}$$

$$Ca + H_2 \xrightarrow{\Delta} \underset{\text{(Calcium hydride)}}{CaH_2}$$

$$NaH + H_2O \longrightarrow NaOH + H_2$$

$$KH + H_2O \longrightarrow KOH + H_2$$

$$CaH_2 + 2H_2O \longrightarrow Ca(OH)_2 + 2H_2$$

(v) Reducing property of Hydrogen :

(a) When **hydrogen gas** is passed over **heated oxides** of **lead, copper** and **zinc**, the **metallic oxides** get **reduced** to their respective **metals** and **hydrogen** gets **oxidized** to **water**.

$$PbO + H_2 \longrightarrow Pb + H_2O$$

$$CuO + H_2 \longrightarrow Cu + H_2O$$

$$ZnO + H_2 \longrightarrow Zn + H_2O$$

(b) **Nascent hydrogen** is a **powerful reducing agent** as compared to **molecular hydrogen**.

(c) **Hydrogen** which is formed **at the time** of **its formation** is called **nascent hydrogen** and is very **short-lived** *i.e.*, it immediately gives **molecular hydrogen**.

(d) **Nascent hydrogen** is prepared **'in situ'**, *i.e.*, at the time of reaction within the reaction medium.

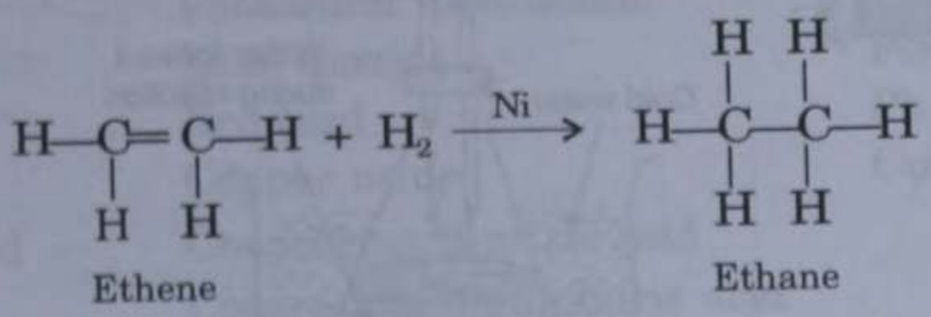
(e) The **pale yellow ferric chloride solution** when mixed with **dilute hydrochloric acid** and **zinc dust**, turns **pale green**, as **ferric chloride** gets **reduced** to **ferrous chloride** by the **nascent hydrogen** which is produced by the reaction of **zinc dust** and **dilute hydrochloric acid.**

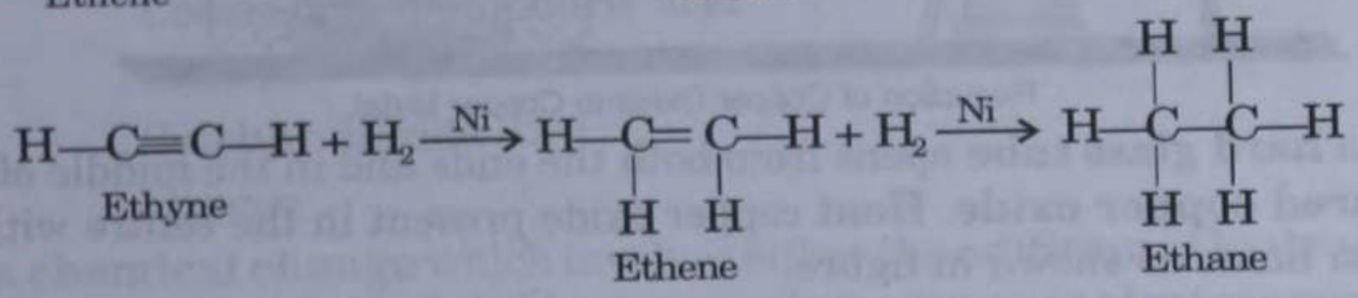
$$Zn + 2HCl \longrightarrow ZnCl_2 + 2[H]$$

$$\underset{\text{Yellow solution}}{FeCl_3} + [H] \longrightarrow \underset{\text{Pale green}}{FeCl_2} + HCl$$

(*vi*) **Hydrogenation.** It is the process of **addition** of **hydrogen** to **alkenes** and **alkynes** in the presence of **nickel** as a **catalyst**. In this process the **unsaturated hydrocarbon** gets converted to **saturated hydrocarbon**.

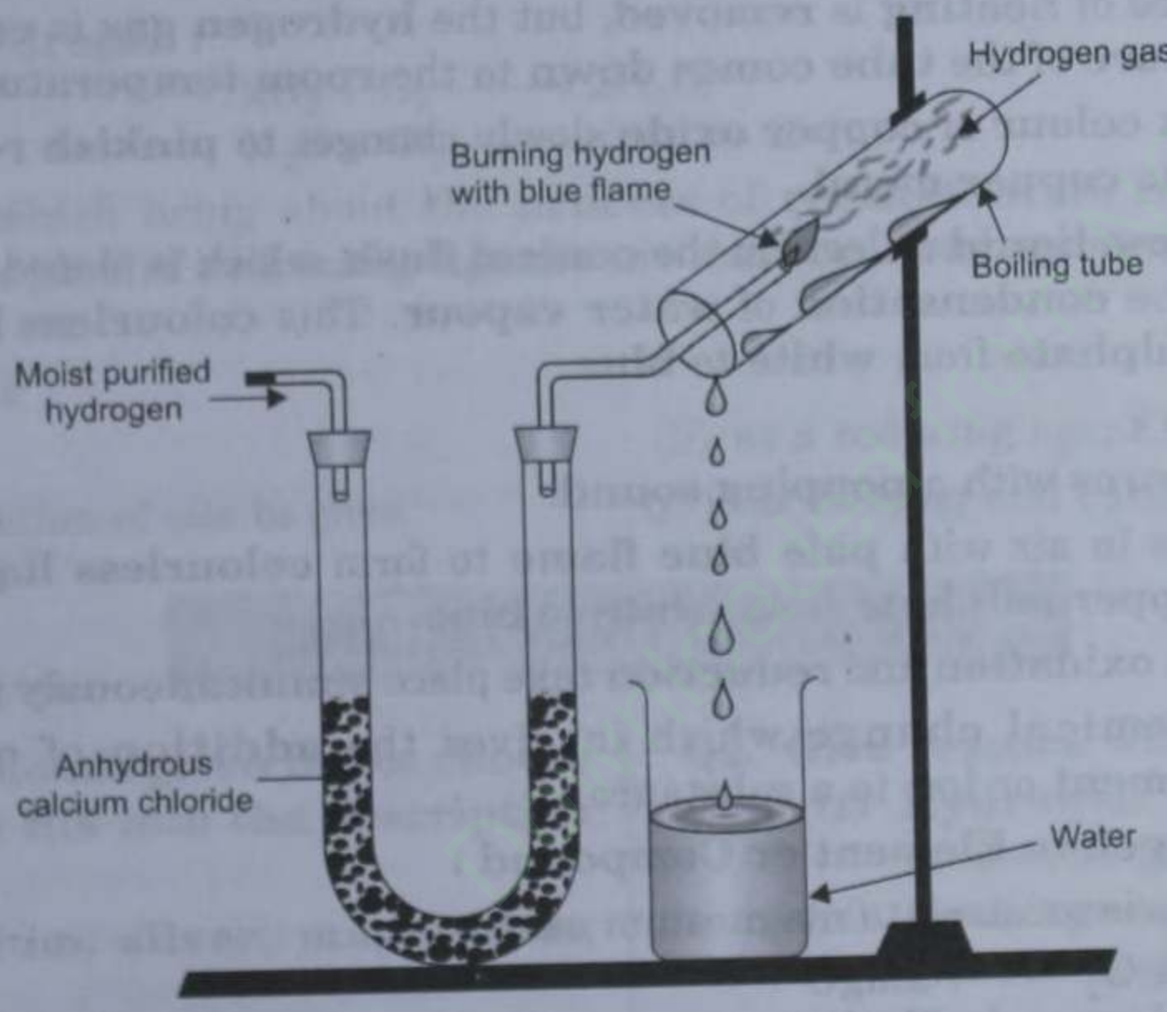
$$C_2H_4 + H_2 \xrightarrow{Ni} C_2H_6$$





21. Important Experiments to Demonstrate the Properties of Hydrogen :

(*i*) To demonstrate that water is the only product formed during combustion of hydrogen in air :



Oxidation of Hydrogen and Formation of Water

(*a*) **Pure hydrogen** is **passed** through **anhydrous calcium chloride** (drying agent). The **pure dry gas** is **burnt** from the jet and the **flame** is **either allowed** to **strike** the **cold surface** of **glass retort** or the **flame** is **allowed** to **burn** in **wide glass boiling tube**.

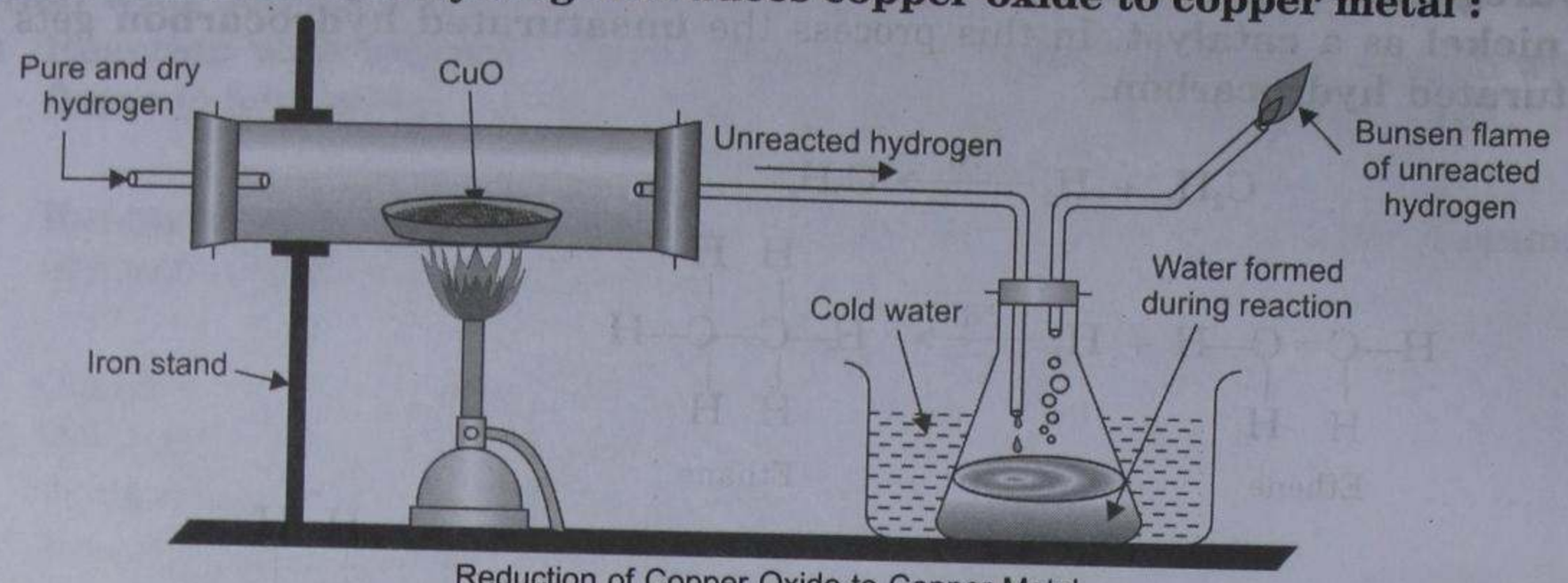
(*b*) In a few moments a **colourless liquid** starts **trickling down** from the **sides** of the **boiling tube** and **collect** in the **beaker** placed below.

(*c*) The **colourless liquid** is **water** and it can be **tested** as

(1) Water turns **anhydrous copper sulphate** from **white** to **blue**.

(2) Water turns **anhydrous cobalt chloride** from **blue** to **pink**.

(ii) To demonstrate that hydrogen reduces copper oxide to copper metal :



Reduction of Copper Oxide to Copper Metal.

(*a*) Take a **hard glass tube** opens from both the ends and in the middle of the tube place **black coloured copper oxide**. **Heat** copper oxide present in the centre with the **non-luminous** bunsen flame as shown in figure.

(*b*) Now **pass pure dry hydrogen** over **heated copper oxide**.

(*c*) **Light a flame** on the **jet tube** so as to **burn** the **unreacted hydrogen**. **Continue passing hydrogen**, till the **flame** at the end of jet tube **grows bigger** in **size**. This clearly indicates that the **reaction** has **completed** and the **hydrogen gas** is **not taking part** in the **reaction**.

(*d*) The **source** of **heating** is **removed**, but the **hydrogen gas** is **continued** to **pass**, till the **temperature** of the **tube comes down** to the **room temperature**.

(*e*) The **black colour** of **copper oxide** slowly changes to **pinkish red**. As **copper oxide** has **reduced** to **copper metal**.

(*f*) A **colourless liquid** collects in the **conical flask**, which is placed in **ice cold water**, which helps in the **condensation** of **water vapour**. This **colourless liquid** turns **anhydrous copper sulphate** from **white** to **blue**.

22. Tests for hydrogen :

(*i*) Hydrogen gas burns with a **popping sound**.

(*ii*) Hydrogen burns in air with **pale blue flame** to form **colourless liquid water**, which turns **anhydrous copper sulphate** from **white** to **blue**.

23. The reaction in which **oxidation** and **reduction** take place **simultaneously** is called **redox reaction**.

24. Oxidation is a **chemical change** which involves the **addition** of **oxygen** or **addition** of **electronegative element** or **ion** to a substance.

(*i*) Addition of Oxygen to Element or Compound :

(*a*) Magnesium is oxidized to magnesium oxide

$$2Mg + O_2 \longrightarrow 2MgO$$

(*b*) Copper is oxidized to copper oxide

$$2Cu + O_2 \longrightarrow 2CuO$$

(*c*) Carbon monoxide is oxidized to carbon dioxide

$$2CO + O_2 \longrightarrow 2CO_2$$

(*d*) Nitrogen monoxide or Nitric oxide is oxidised to nitrogen dioxide.

$$2NO + O_2 \longrightarrow 2NO_2$$

(*ii*) Addition of Electronegative Element or Ion :

$$2FeCl_2 + Cl_2 \longrightarrow 2FeCl_3$$

25. Oxidation can also be defined as the **removal** of **hydrogen** or the **electropositive element** or **ion** from a substance.

$$H_2S + Cl_2 \longrightarrow 2HCl + S$$

26. Oxidizing agents are those which **brings about** the **process** of **oxidation**, *i.e.*, it **oxidizes** other substances.

27. Examples of oxidizing agents are

(*i*) Solid —	Potassium permanganate	$KMnO_4$
	Potassium dichromate	$K_2Cr_2O_7$
	Lead dioxide	PbO_2
	Red lead	Pb_3O_4
	Copper oxide	CuO
(*ii*) Liquid —	Concentrated nitric acid	
	Concentrated sulphuric acid	
(*iii*) Gases —	Chlorine	
	Sulphur dioxide	
	Oxygen	

28. Reduction is a **chemical change** which involves either the **addition** of **hydrogen** or **electropositive element** to the substance or it involves the **removal** of **oxygen** or **electronegative element** from the substance.

(*i*) Removal of oxygen :

$$ZnO + H_2 \longrightarrow Zn + H_2O$$
$$CuO + C \longrightarrow Cu + CO$$

(*ii*) Addition of hydrogen :

$$2H_2 + O_2 \longrightarrow 2H_2O$$
$$H_2S + Cl_2 \longrightarrow 2HCl + S$$

29. The **substances** which bring about the **process** of **reduction** are called **reducing agents** or **reductants**. **Examples** of **reducing agents** are **carbon, carbon monoxide, sulphur dioxide, hydrogen iodide**, etc.

30. Hydrogen is used

(*i*) as a fuel.
(*ii*) as a reducing agent in metallurgy.
(*iii*) for hydrogenation of oils to ghee.
(*iv*) for welding and cutting of metals.

IMPORTANT POINTS TO REMEMBER

Q1. From the list of metals given below choose the metal which fits into the description given below :
Iron, zinc, sodium, silver, magnesium, lead.

(*i*) A metal which reacts very slowly with dilute hydrochloric acid initially but after sometime reaction stops.
(*ii*) A metal that reacts reversibly with steam.
(*iii*) A metal which reacts vigorously with cold water.
(*iv*) A metal which does not react with dilute acid or water.
(*v*) A metal which reacts both with acids and alkalies to displace hydrogen.

Ans. (*i*) Lead (*ii*) Iron
(*iii*) Sodium (*iv*) Silver
(*v*) Zinc.

Q2. Give reasons why

(*i*) Hydrogen was previously used in meteorological balloons.
(*ii*) Hydrogen is no longer used in meteorological balloons.
(*iii*) Hydrogen is not collected in air.
(*iv*) Hydrogen is used as a fuel.
(*v*) Hydrogen obtained by the reaction of zinc and dilute sulphuric acid has a peculiar smell.
(*vi*) Hydrogen obtained by Bosch process is passed through ammoniacal cuprous chloride.
(*vii*) Hydrogen manufactured by Bosch process is passed through water under pressure.
(*viii*) Hydrogen is not prepared by the reaction of aluminium with dilute acids.

(*ix*) In laboratory, hydrogen is not prepared by the reaction of lead with dilute sulphuric acid or dilute hydrochloric acid.

(*x*) The apparatus used for the preparation of hydrogen must be airtight.

Ans. (*i*) Hydrogen was previously used in meteorological balloons because of its lowest density and high lifting power.

(*ii*) Hydrogen is now no longer used in meteorological balloons as it is highly inflammable in nature. *i.e.*, it catches fire very easily.

(*iii*) Hydrogen is not collected in air because it forms explosive mixture with air.

(*iv*) Hydrogen is used as a fuel because it on burning produces large amount of heat energy, *i.e.*, it has high calorific value.

(*v*) Hydrogen has peculiar smell because it contains the impurities of arsine and phosphine.

(*vi*) Hydrogen obtained by Bosch process is passed through ammoniacal cuprous chloride solution so as to absorb carbon monoxide.

(*vii*) Hydrogen obtained by Bosch process is passed through water under pressure to remove carbon dioxide.

(*viii*) Aluminium is not used for preparation of hydrogen from acids because a thin but a tough layer of oxide is formed which prevents the further reaction of acid with metal.

(*ix*) In laboratory hydrogen is not prepared by the reaction of lead with dilute sulphuric acid or dilute hydrochloric acid because it forms insoluble lead sulphate and insoluble lead chloride respectively which prevents the reaction of metals with acids.

(*x*) The apparatus used for the preparation of hydrogen must be airtight because any leakage can cause explosion as hydrogen is highly inflammable.

Q3. When neutral gas 'A' which burns with popping sound is passed through boiling yellow non-metal 'B' it forms gas 'C'.

(*i*) Identify A, B and C.

(*ii*) Give balanced chemical equation for the reaction.

(*iii*) Give the characteristic odour of gas 'C'.

(*iv*) Give the confirmatory test of gas 'C'.

(*v*) Name the oxidation product of gas 'A'. Give two tests for the named product.

Ans. (*i*) A = Hydrogen B = Sulphur

C = Hydrogen sulphide

(*ii*) $\underset{\text{'A'}}{H_2} + \underset{\substack{\text{boiling}\\ \text{'B'}}}{S} \longrightarrow \underset{\text{'C'}}{H_2S}$

(*iii*) Rotten egg smell.

(*iv*) Gas 'C' turns lead acetate solution black.

(*v*) The oxidation product of gas 'A' is water.

The two tests for water are :

(*a*) It turns anhydrous copper sulphate from white to blue.

(*b*) It turns anhydrous cobalt chloride from blue to pink.

Q4. Fill in the blanks :

(*a*) To the iron (III) chloride solution which is (*i*) _____ in colour (*ii*) _____ is added with dilute hydrochloric acid to produce (*iii*) _____ hydrogen. The colour of the solution changes from (*iv*) _____ to (*v*) _____ and it undergoes the process of (*vi*) _____.

(*b*) When hydrogen is passed over heated (*i*) _____ which is black in colour it forms (*ii*) _____ copper metal. Hydrogen in this reaction is acting as (*iii*) _____ agent.

(*c*) Hydrogen is prepared in laboratory by the reaction of (*i*) _____ with dilute sulphuric acid. The hydrogen obtained is not pure. It contains the impurities of (*ii*) _____ , (*iii*) _____ , (*iv*) _____ , (*v*) _____ (*vi*) _____ and (*vii*) _____ . The impure hydrogen is passed through silver nitrate solution to remove (*viii*) _____ and (*ix*) _____ . Then the impure hydrogen is passed through lead nitrate solution to remove (*x*) _____ . Then finally hydrogen is passed through potassium hydroxide solution and anhydrous calcium chloride to

remove (*xi*) _____, (*xii*) _____, (*xiii*) _____ and (*xiv*) _____ respectively to get (*xv*) _____ hydrogen.

Ans. (*a*) (*i*) Yellow (*ii*) Zinc
(*iii*) Nascent (*iv*) Yellow
(*v*) Pale green (*vi*) Reduction
(*b*) (*i*) Copper oxide (*ii*) Pinkish red
(*iii*) Reducing agent.
(*c*) (*i*) Zinc (*ii*) Arsine
(*iii*) Phosphine (*iv*) Nitrogen dioxide
(*v*) Carbon dioxide (*vi*) Sulphur dioxide
(*vii*) Moisture (*viii*) Arsine
(*ix*) Phosphine
(*x*) Hydrogen sulphide
(*xi*) Carbon dioxide
(*xii*) Sulphur dioxide
(*xiii*) Nitrogen dioxide
(*xiv*) Moisture
(*xv*) Pure.

Q5. The following questions are related to the manufacture of hydrogen by the Bosch process.

(*i*) Give equation for the preparation of water gas.

(*ii*) Why the temperature of charcoal falls down during the formation of water gas ?

(*iii*) Give equation for the water gas shift reaction.

(*iv*) Name the catalyst and the promoter used during water gas shift reaction.

(*v*) Name the two other gases which are produced along with hydrogen.

(*vi*) How are the above named gases removed from hydrogen ?

Ans. (*i*) $\underset{\text{White hot charcoal}}{C} + \underset{\text{Super heated steam}}{H_2O} \xrightarrow{170^\circ C} \underbrace{CO + H_2}_{\substack{\text{Equivolume mixture of CO and } H_2 \\ \text{(Water gas)}}}$

(*ii*) The reaction of superheated steam with coke/charcoal is endothermic in nature therefore, the temperature of coke falls down.

(*iii*) $\underbrace{CO + H_2}_{\text{Water gas}} + H_2O \xrightarrow[450^\circ C]{Fe_2O_3/Cr_2O_3} CO_2 + 2H_2$

(*iv*) Catalyst — Ferric oxide
Promoter — Chromium oxide.

(*v*) Carbon dioxide and carbon monoxide.

(*vi*) Carbon dioxide is removed by passing it through water under pressure.
Carbon monoxide is removed by passing it through ammoniacal cuprous chloride solution.

Q6. Two neutral gases 'A' and 'B' undergo synthesis reaction to form a basic gas 'C'.

(*i*) Identify A, B and C.

(*ii*) Name the process by which gas 'C' is manufactured. Give balanced chemical equation also.

(*iii*) What do you observe when gas 'C' comes in contact with
(*a*) moist red litmus paper ?
(*b*) concentrated hydrochloric acid ?

Ans. (*i*) A : Nitrogen B : Hydrogen
C : Ammonia

(*ii*) Haber's process :

$$N_2 + 3H_2 \underset{\substack{450\text{-}500^\circ C \\ 200\text{-}1000 \text{ atm}}}{\overset{\text{Fe-Mo}}{\rightleftharpoons}} 2NH_3$$

(*iii*) (*a*) It turns blue.
(*b*) It gives dense white fumes.

Q7. Name the following.

(*i*) Two metals which react with dilute nitric acid to liberate hydrogen.

(*ii*) Two metals which do not displace hydrogen from dilute acids.

(*iii*) A salt soluble in hot water but insoluble in cold water.

(*iv*) A salt insoluble in all the mineral acids.

(*v*) A gas which forms explosive mixture with air.

(*vi*) A gas having rotten egg smell.

(*vii*) A gas which turns lead acetate solution black.

(*viii*) Equivolume mixture of carbon monoxide and hydrogen.

Ans. (*i*) Magnesium and manganese
(*ii*) Copper and silver

(*iii*) Lead chloride

(*iv*) Lead sulphate, calcium sulphate or barium sulphate

(*v*) Hydrogen

(*vi*) Hydrogen sulphide

(*vii*) Hydrogen sulphide

(*viii*) Water gas.

Q8. Copy, complete and balance the following equations :

(*i*) $K + H_2O \longrightarrow$ **(*ii*) $Na + H_2O \xrightarrow[cold]{} $**

(*iii*) $Mg + H_2O \xrightarrow[steam]{} $ **(*iv*) $Zn + H_2O \xrightarrow[steam]{} $**

(*v*) $Fe + H_2O \xrightarrow[steam]{} $ **(*vi*) $Na + HCl \longrightarrow$**

(*vii*) $K + HCl \longrightarrow$ **(*viii*) $Ca + HCl \longrightarrow$**

(*ix*) $Mg + HCl \longrightarrow$ **(*x*) $Mg + H_2SO_4 \longrightarrow$**

(*xi*) $Mg + HNO_3 \longrightarrow$ **(*xii*) $Mn + HNO_3 \longrightarrow$**

(*xiii*) $Zn + H_2SO_4 \longrightarrow$ **(*xiv*) $Zn + NaOH \longrightarrow$**

(*xv*) $Zn + KOH \longrightarrow$

Ans. (*i*) $2K + 2H_2O \text{ (cold)} \longrightarrow 2KOH + H_2$

(*ii*) $2Na + 2H_2O \text{ (cold)} \longrightarrow 2NaOH + H_2$

(*iii*) $Mg + H_2O \text{ (steam)} \longrightarrow MgO + H_2$

(*iv*) $Zn + H_2O \text{ (steam)} \longrightarrow ZnO + H_2$

(*v*) $3Fe + 4H_2O \underset{\text{steam}}{\overset{\text{heated}}{\rightleftharpoons}} Fe_3O_4 + 4H_2$

(*vi*) $2Na + 2HCl \longrightarrow 2NaCl + H_2$

(*vii*) $2K + 2HCl \longrightarrow 2KCl + H_2$

(*viii*) $Ca + 2HCl \longrightarrow CaCl_2 + H_2$

(*ix*) $Mg + 2HCl \longrightarrow MgCl_2 + H_2$

(*x*) $Mg + H_2SO_4 \longrightarrow MgSO_4 + H_2$

(*xi*) $Mg + 2HNO_3 \xrightarrow{\text{V. dil.}} Mg(NO_3)_2 + H_2$

(*xii*) $Mn + 2HNO_3 \xrightarrow{\text{V. dil.}} Mn(NO_3)_2 + H_2$

(*xiii*) $Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$

(*xiv*) $Zn + 2NaOH \longrightarrow Na_2ZnO_2 + H_2$

(*xv*) $Zn + 2KOH \longrightarrow K_2ZnO_2 + H_2$

Q9. Pure hydrogen burns in pure oxygen with a flame and it forms droplets of colourless liquid 'A'.

(*i*) What is the colour of the flame ?

(*ii*) Identify 'A'

Ans. (*i*) Pale blue flame.

(*ii*) Water.

Q10. What is the purpose of oxyhydrogen flame ?

Ans. It is used for welding and cutting of metals.

Q11. Metallic hydrides react with water to produce liquid 'A' and gas 'B'. In this context answer the following questions.

(*i*) Identify 'A' and 'B'.

(*ii*) What is the effect of adding neutral litmus solution to 'A' ?

(*iii*) What do you observe when burning splinter comes in contact with gas 'B' ?

Ans. (*i*) 'A' = Metallic hydroxide

'B' = Hydrogen

(*ii*) It turns blue

(*iii*) The splinter extinguishes and the gas burns with a popping sound.

Q12. Write balanced chemical equations only for the reaction of hydrogen with

(*i*) Oxygen

(*ii*) Sulphur

(*iii*) Chlorine

(*iv*) Copper oxide

(*v*) Ethene.

Ans. (*i*) $2H_2 + O_2 \longrightarrow 2H_2O$

(*ii*) $H_2 + S \longrightarrow H_2S$

(*iii*) $H_2 + Cl_2 \longrightarrow 2HCl$

(*iv*) $CuO + H_2 \longrightarrow Cu + H_2O$

(*v*) $C_2H_4 + H_2 \longrightarrow C_2H_6$

LET'S RECALL

Fill Your Answer in the Space Given for Each Question.

Q1. Match the following :

Column I	Column II
(*i*) Hydrogen sulphide	(*a*) Bosch process
(*ii*) Ammonia	(*b*) Oxidation product
(*iii*) Hydrogen	(*c*) Strong affinity for hydrogen
(*iv*) Water	(*d*) Rotten egg smell
(*v*) Chlorine	(*e*) Haber's process

Ans. (*i*) ☐ (*ii*) ☐ (*iii*) ☐ (*iv*) ☐ (*v*) ☐

Q2. Fill in the blanks.

(*i*) Nascent hydrogen is a powerful _____ agent.

(*ii*) Pure hydrogen burns in pure oxygen with _____ flame.

(*iii*) Water gas is a mixture of _____ and _____ .

(*iv*) Nitric acid only gives hydrogen on reaction with _____ and _____ .

(*v*) _____ reacts reversibly with steam.

(*vi*) Although aluminium is highly _____ element yet its reaction with water and dilute acids is _____ .

(*vii*) During the electrolysis of acidulated water _____ is obtained at cathode and _____ is obtained at anode.

(*viii*) The process of addition of hydrogen is _____ which takes place in the presence of _____ catalyst.

(*ix*) Metallic hydrides are quiet _____ and reacts with water to liberate _____.

(*x*) Hydrogen is a _____ gas but a _____ of combustion.

Q3. State whether the following statements are True or False.

(*i*) Hydrogen is neutral towards litmus. ☐

(*ii*) Normal hydrogen is deuterium. ☐

(*iii*) Molecular hydrogen is a powerful reducing agent than nascent hydrogen. ☐

(*iv*) Zinc reacts with caustic alkalies to liberate hydrogen. ☐

(*v*) Chlorine reacts moderately with hydrogen in diffused sunlight. ☐

Q4. Each question has four options out of which only one option is correct. Dark the bubble for correct answer.

(*i*) The catalyst used during Haber's process is

(*a*) platinum
(*b*) zinc
(*c*) iron
(*d*) copper

Ans. (a) (b) (c) (d)

(*ii*) The promoter used during Haber's process is

(*a*) molybdenum (*b*) copper

(*c*) zinc (*d*) lead

Ans. (a) (b) (c) (d)

(*iii*) The metal which does not displace hydrogen from dilute acid is

(*a*) sodium (*b*) copper

(*c*) zinc (*d*) iron

Ans. (a) (b) (c) (d)

(*iv*) On addition of hydrogen ethene gets converted to

(*a*) ethyne (*b*) methane

(*c*) propane (*d*) ethane

Ans. (a) (b) (c) (d)

(*v*) On adding water to sodium the solution formed is

(*a*) neutral (*b*) alkaline

(*c*) acidic (*d*) amphoteric

Ans. (a) (b) (c) (d)

Q5. Complete and balance the following equations.

(*i*) $Al + NaOH + H_2O \longrightarrow$ _____ + _____

(*ii*) $N_2 + H_2 \longrightarrow$ _____

(*iii*) $CaH_2 + H_2O \longrightarrow$ _____ + _____

(*iv*) $Fe + H_2SO_4 \longrightarrow$ _____ + _____

(*v*) $Fe + HCl \longrightarrow$ _____ + _____

(*vi*) $CuO + H_2 \longrightarrow$ _____ + _____

(*vii*) $H_2S + Cl_2 \longrightarrow$ _____ + _____

(*viii*) $Na + H_2O \longrightarrow$ _____ + _____

(*ix*) $Fe + H_2O \rightleftharpoons$ _____ + _____

(*x*) $Zn + H_2O \longrightarrow$ _____ + _____

Answers

1. (*i*) *d* (*ii*) *e* (*iii*) *a* (*iv*) *b* (*v*) *c*

2. (*i*) reducing (*ii*) pale blue (*iii*) carbon monoxide, hydrogen
(*iv*) magnesium, manganese (*v*) iron (*vi*) electropositive, slow
(*vii*) hydrogen, oxygen (*viii*) hydrogenation, nickel (*ix*) unstable, hydrogen
(*x*) combustible, not a supporter

3. (*i*) True (*ii*) False (*iii*) False (*iv*) True (*v*) True

4. (*i*) *c* (*ii*) *a* (*iii*) *b* (*iv*) *d* (*v*) *b*

5. (*i*) $2Al + 2NaOH + 2H_2O \longrightarrow 2NaAlO_2 + 3H_2$

(*ii*) $N_2 + 3H_2 \longrightarrow 2NH_3$

(*iii*) $CaH_2 + 2H_2O \longrightarrow Ca(OH)_2 + 2H_2$

(*iv*) $Fe + H_2SO_4 \longrightarrow FeSO_4 + H_2$

(*v*) $Fe + 2HCl \longrightarrow FeCl_2 + H_2$

(*vi*) $CuO + H_2 \longrightarrow Cu + H_2O$

(*vii*) $H_2S + Cl_2 \longrightarrow 2HCl + S$

(*viii*) $2Na + 2H_2O \longrightarrow 2NaOH + H_2$

(*ix*) $3Fe + 2H_2O \rightleftharpoons Fe_3O_4 + 4H_2$

(*x*) $Zn + H_2O \longrightarrow ZnO + H_2$

SELF EVALUATION TEST

***Time** : 30 minutes* ***Marks** : 30*

Q1. What is the atomicity of hydrogen ? **1**

Q2. In free state, where hydrogen occurs ? Why does it rarely occur in free state ? **2**

Q3. Name two metals which react both with acids and alkalies to liberate hydrogen. Support your answer with balanced chemical equations. **4**

Q4. Give reasons why **5**

(*i*) during the laboratory preparation of hydrogen no flame should be kept near the apparatus.

(*ii*) hydrogen is not collected in air but is collected over water.

(*iii*) hydrogen obtained from granulated zinc has a peculiar smell.

(*iv*) colour of ferric chloride changes when it comes in contact with zinc and dilute hydrochloric acid.

(*v*) lead is not used for the preparation of hydrogen from dilute hydrochloric acid or dilute sulphuric acid.

Q5. Name the process by which hydrogen is manufactured. Give all details of the process. **5**

Q6. Hydrogen obtained during its laboratory preparation contains certain impurities. Name the impurities and how these impurities can be removed ? **6**

Q7. A black metallic oxide 'A' on reaction with colourless and odourless gas 'B' forms pinkish red metal 'C' and colourless liquid 'D'. **7**

(*i*) Identify A, B, C and D.

(*ii*) Give balanced chemical equation for the reaction.

(*iii*) What is the purpose of gas 'B' ?

(*iv*) Name the above reaction.

(*v*) Give two tests for colourless liquid 'D'.